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Production performance of beef cows raised on three different nutritionally controlled heifer development programs[1,2]

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ABSTRACT: The objective of this study was to determine primiparous heifer performance following three different heifer development strategies that were the result of timed nutrient limitation. Two hundred eighty-two spring-born MARC III heifers were weaned at 203 ± 1 d of age and 205 ± 1 kg BW. The experiment was conducted on two calf crops with 120 heifers born in 1996 and 162 heifers born in 1997. Treatments consisted of different quantities of the same diet being offered for a 205-d period. Heifers in the HIGH treatment were offered 263 kcal ME/$(BW_{kg})^{0.75}$ daily. Heifers in the MEDIUM treatment were offered 238 kcal ME/$(BW_{kg})^{0.75}$ daily. Heifers in the LOW-HIGH treatment were offered 157 kcal ME/$(BW_{kg})^{0.75}$ daily the first 83 d and 277 kcal ME/$(BW_{kg})^{0.75}$ daily for the remainder of the 205 d. Treatments differed in total ME intake ($P < 0.001$); heifers on the HIGH treatment consumed 3,072 ± 59 Mcal/heifer, those on the MEDIUM treatment consumed 2,854 ± 21 Mcal/heifer, and those on the LOW-HIGH treatment consumed 2,652 ± 19 Mcal/heifer. At the beginning of breeding, heifers on the HIGH treatment were taller at the hips ($P = 0.01$) and weighed more ($P < 0.001$) than heifers in the other two treatments. The percentage of heifers that calved expressed as a fraction of the cows exposed did not differ among treatments (89.7%; $P = 0.83$). The age of heifer at parturition ($P = 0.74$) and the time from first bull exposure to calving ($P = 0.38$) did not differ among treatments. Birth weight of calves ($P = 0.80$) and the calves' weaning weight ($P = 0.60$) did not differ among the treatments. Calf survival rate on the LOW-HIGH treatment (73%) was lower than that on the moderate treatment (89%; $P = 0.007$) but did not differ from that on the HIGH treatment (81%; $P = 0.26$). The second-calf pregnancy rate (92.8%) for cows with a nursing calf at the start of breeding did not differ between treatments ($P = 0.83$). These findings suggest that as long as heifers are growing and meet a minimal BW before mating, patterns of growth may be altered in the postweaning period without a decrease in the ability of the heifer to conceive or a decrease in calf growth potential. However, limit-feeding heifers may decrease first-calf survival. These alterations in postweaning gain through monitoring the amount of feed offered can be used to optimize feed resources.

Key Words: Cattle, Development, Growth, Weight Gain

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Introduction

A portion of the heifer calves born must be retained for use as replacements in order to sustain the cow herd. The proportion retained is dependent on culling strategies, but typically 15 to 20% of the bred females are replaced annually, which requires 35 to 55% of the weaned females to be retained as replacements. Because the single largest production cost in raising heifers is feed, decreasing feed associated with heifer development may offer a potential management strategy to reduce heifer development cost. However, it has been demonstrated in numerous studies that age and BW at puberty are influenced by level of nutrition (Jourbert, 1954; Wiltbank et al., 1969; Ferrell, 1982). These studies suggest that heifers need to attain a minimum percentage of their mature BW (55 to 60%) to ensure maximum pregnancy rates. The studies of Clanton et al. (1983) and Lynch et al. (1997) suggest the phenomenon of compensatory gain can be used to reduce feed input into heifer development programs and still attain the minimum weight required for heifers to reach sexual maturity.

However, altering prepuberal growth patterns can affect the onset of puberty (Lynch et al., 1997) as well as change the milk production potential of the cow

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[2]Names are necessary to report factually on available data; however, the USDA neither guarantees nor warrants the standard of the product, and the use of the name by USDA implies no approval of the product to the exclusion of others that may also be suitable.

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(Gardner et al., 1977; Little and Kay, 1979). The objective of this study was to determine performance of primiparous cows following three different heifer development strategies that were the result of timed nutrient limitation.

Materials and Methods

Animal Management

Two hundred eighty-two spring-born MARC III (four breed composite: 1/4 Hereford, 1/4 Angus, 1/4 Red Poll, 1/4 Pinzgauer) heifers were weaned at 203 ± 1 d of age and 205 ± 1 kg BW. The experiment was conducted on two calf crops with 120 heifers born in 1996 and 162 heifers born in 1997. Average daily gain was determined from July until September while heifers were nursing their dams on pasture and heifers were randomly assigned within ADG to one of six pens at weaning. In the 1st yr, 20 heifers were placed in each pen, and in the 2nd yr, 27 heifers were placed in each pen. Pens were 1,027 m^2 in size. Each heifer had 0.56 to 0.61 m of feeder space. Each year, two pens were assigned to each of three treatments.

Treatments consisted of different quantities of the same diet being offered over a 205-d development period. From weaning until 46 d after weaning, heifers received a diet that was 43.6% chopped alfalfa hay, 34.0% cracked corn, 20% corn silage, and 2.4% liquid supplement on a DM basis. The supplement was 75% CP, which included a nonprotein nitrogen content of 71%, 11% Ca, 1% P, 70 kIU vitamin A/kg, 152 IU vitamin E/kg, and 0.306 g monensin/kg. The diet had a calculated ME of 2.55 Mcal/kg and a CP of 14.2% on a DM basis. From 47 to 205 d after weaning, heifers received a diet that was 89.8% corn silage, 4.0% chopped alfalfa hay, 3.6% limestone, 0.4% sodium chloride, and 2.2% urea on a DM basis. The diet had a calculated ME of 2.35 Mcal/kg and a CP of 14.1% on a DM basis. The feeding period was divided into two phases and six periods. Phase 1 contained Periods 1 and 2. Period 1 was weaning to 42 d, and Period 2 was 43 to 84 d. Phase 2 contained Periods 3 through 6. Period 3 was 85 to 112 d, Period 4 was 113 to 140 d, Period 5 was 141 to 168 d, and Period 6 was 169 to 205 d. Heifers in the HIGH treatment were offered 263 kcal ME/$(BW_{kg})^{0.75}$ daily during Phases 1 and 2. Heifers in the MEDIUM treatment were offered 238 kcal ME/$(BW_{kg})^{0.75}$ daily during Phases 1 and 2. Heifers in the LOW-HIGH treatment were offered 157 kcal ME/$(BW_{kg})^{0.75}$ daily during Phase 1 and 277 kcal ME/$(BW_{kg})^{0.75}$ daily during Phase 2. Heifers were fed twice daily. Feed refusals were determined weekly.

Heifers were weighed at weaning and at 42, 84, 112, 140, 168, and 205 d after weaning. Gain:ME intake ratios were calculated as the difference in starting and ending BW of the pen divided by the pen ME intake for the same period. At 205 d heifers were removed from the drylot pens and placed in a breeding pasture. Pastures consisted primarily of brome grass and no additional feed was provided during breeding. After heifers were removed from the drylot, pens were commingled and heifers within year were managed together for the rest of the study. At the beginning of the breeding season, heifers were 412 ± 1 d of age. MARC III bulls were used for natural service with a bull:heifer ratio of 1:25. Bulls remained with the heifers for 63 d, and heifers were rectally palpated 72 d after bull removal to determine whether they were pregnant. Heifers were weighed at the beginning and end of the breeding season and at the time of palpation. Heifers were kept on pasture during the winter. Beginning approximately December 1 of each year heifers were fed a corn silage-alfalfa haylage-based diet in addition to pasture. Supplementation was stopped approximately May 1 of each year. The supplemental feed provided approximately 23 Mcal ME/heifer daily from December through February and 28 Mcal ME/heifer daily for the rest of the supplementation period.

Calf weights were measured at birth, and subsequent weights were taken 7, 11, 15, and 19 wk after the first calf was born. Each cow was weighed at parturition and 7, 11, and 15 wk after the first calf was born. Calves were weaned at 218 ± 1 d of age and cows and calves were weighed. This procedure resulted in each calf being weighed at least five times from birth to weaning. When cows were 81 ± 1 d postpartum they were exposed to MARC III bulls for 63 d. Cows were rectally palpated to determine pregnancy 13 wk after bulls were removed. Experimental procedures were conducted in accordance with the Meat Animal Research Center Animal Care Guidelines and the *Guide for the Care and Use of Agricultural Animals in Agricultural Research and Teaching* (FASS, 1999).

Statistical Analysis

Second-order polynomial regressions in Phase 1 and fourth-order polynomial regressions in Phase 2 were used to fit the relationship between BW and time to individual animals. Animals were the experimental unit and regression coefficients were analyzed as a two-way ANOVA. The model included treatment, birth year, and the interaction of treatment × birth year. Metabolizable energy intake and gain:ME intake ratios were analyzed as a two-way ANOVA with pen as the experimental unit. The model included treatment, birth year, and the interaction of treatment × birth year. The above data were analyzed using the GLM procedure in SAS v. 6.1 (SAS Inst. Inc., Cary, NC).

Individual animal was considered the experimental unit on all data collected following the developmental period. Weight and height data at breeding and palpation and weight and age data at parturition were analyzed as a two-way ANOVA. The model included treatment, birth year, and the interaction of treatment × birth year. The above data were analyzed using the GLM procedure in SAS v. 6.1 (SAS Inst. Inc.).

Percentage of cows diagnosed pregnant and calving percentage were tested using the Maximum Likelihood Estimates with treatment, birth year, and the interaction as the variables. Calving difficulty was measured as a binomial response whereby cows were classified as either requiring assistance or not requiring assistance and was tested using the Maximum Likelihood Estimates with treatment, birth year, calf sex, and the two-way interactions as the variables. Data for pregnancy diagnoses, calving percentage, and calving difficulty were analyzed using the GENMOD procedure in SAS v. 6.1 (SAS Inst. Inc.) with a binomial distribution specification.

Body weight of the calves at 30, 60, 90, 120, 150, and 180 d of age and BW of cows at 30, 60, and 90 d postpartum were estimated by fitting individual animal polynomial regressions of BW on time and then solving the regression for time. The order of the regression was determined as the total number of observed BW minus 1. Estimated BW and BW at weaning were initially analyzed with a model that included treatment, birth year, and calf sex as fixed effects, Julian birth date as a covariant, and all of the two-way interactions. The model was subsequently reduced using a step-down approach that removed terms that did not contribute to reducing the sums of squares, which was defined to be when the F-value for a term was less than 1. Data were analyzed using the GLM procedure in SAS v. 6.1 (SAS Inst. Inc.).

Means and standard errors are presented in the text and tables. Means were tested using protected single degree of freedom contrasts, and means with probabilities less than 0.05 were considered to be different and means with probabilities ≥ 0.05 and < 0.10 were considered to tend to differ.

Results

During the course of the study a number of animals were removed from the study for a variety of causes (Table 1). Within a cause of removal, treatments did not differ in the number of animals that were removed (Table 1).

Weaning to Breeding

At weaning, heifers were 203 ± 1 d of age and weighed 205 ± 1 kg. Age at weaning did not differ across years ($P = 0.17$), but heifers were heavier (211 ± 2 kg; $P < 0.001$) at weaning in 1997 than in 1996 (196 ± 2 kg). During Phase 1, heifers on all treatments gained weight (Table 2), and there was a treatment × year interaction for weight gain ($P < 0.001$). In 1996, HIGH heifers gained 52.0 ± 1.6 kg, MEDIUM heifers gained 38.0 ± 1.7 kg, and LOW-HIGH heifers gained 17.7 ± 1.9 kg. In 1997, HIGH heifers gained 64.0 ± 1.9 kg, MEDIUM heifers gained 50.3 ± 1.8 kg, and LOW-HIGH heifers gained 16.6 ± 1.6 kg. During Phase 2, heifers on all treatments gained weight (Table 2), and there was a

Table 1. Summary of causes for animal removal

		Cow removal					Calf removal					
		Prepartum			Postpartum		Calf died					
Treatment[a]	Total on study	Breeding injury	Open as yearling	Aborted	Twins	Lactation injury	Birth	< 72 h	> 72 h	Calf rejected	Calf out of pen	Open as 2-yr-old
HIGH	94	0	9	1	0	0	4	3	9	0	2	6
MEDIUM	94	0	7	2	0	0	2	1	6	0	1	7
LOW-HIGH	94	1	8	2	2	1	5	6	9	1	0	3
Overall	282	1	24	5	2	1	11	10	24	1	3	16

[a]Treatments differed in the amount of daily feed offered from weaning to 205 d of age: HIGH = 263 kcal ME/$(BW_{kg})^{0.75}$, MEDIUM = 238 kcal ME/$(BW_{kg})^{0.75}$, and LOW-HIGH = 157 kcal ME/$(BW_{kg})^{0.75}$ for the first 83 d and 277 kcal ME/$(BW_{kg})^{0.75}$ for the rest of the 205 d.

Table 2. Means and standard errors for the polynomial regression coefficients for body weight as a function of days during the period of feed restriction (Phase 1) and during the period of increased feed offered (Phase 2)

		Coefficients for body weight, kg							
		Phase 1: $f(x) = b_2x^2 + b_1x + b_0$, where x = 0→84			Phase 2: $f(x) = b_4x^4 + b_3x^3 + b_2x^2 + b_1x + b_0$, where x = 0→121				
Treatment[a]	n	$b_2 \times 10^{-7}$	$b_1 \times 10^{-4}$	b_0	$b_4 \times 10^{-7}$	$b_3 \times 10^{-7}$	$b_2 \times 10^{-6}$	$b_1 \times 10^{-4}$	b_0
HIGH		–3,716 ± 3,389	7,321 ± 373	205 ± 2	–1.7667 ± 1.9883	204 ± 449	348 ± 3,101	6,733 ± 650	264 ± 3
1996	40	5,657 ± 4,213	5,713 ± 401	197 ± 3	2.6304 ± 2.7441	–914 ± 633	9,226 ± 4,541	5,859 ± 1,038	249 ± 3
1997	54	–10,659 ± 4,824	8,511 ± 523	210 ± 3	–5.0238 ± 2.7387	1,033 ± 605	–6,228 ± 4,028	7,380 ± 826	274 ± 3
MEDIUM		–10,552 ± 3,180	6,255 ± 368	206 ± 2	–10.8673 ± 1.6756	2,005 ± 383	–8,737 ± 2,721	6,804 ± 677	251 ± 3
1996	40	–321 ± 4,388	4,555 ± 483	196 ± 3	–16.4415 ± 2.2279	3,093 ± 518	–13,123 ± 3,851	6,454 ± 1,058	234 ± 3
1997	54	–18,130 ± 4,226	7,515 ± 464	213 ± 3	–6.7382 ± 2.2614	1,198 ± 521	–5,488 ± 3,750	7,062 ± 887	263 ± 4
LOW-HIGH		–26,263 ± 3,727	4,243 ± 376	205 ± 2	–14.2165 ± 1.6857	3,185 ± 397	–23,847 ± 2,924	15,903 ± 688	221 ± 2
1996	40	–11,571 ± 4,141	3,083 ± 461	196 ± 3	–11.1561 ± 2.6986	2,409 ± 642	–16,450 ± 4,819	14,449 ± 1,183	214 ± 3
1997	54	–37,146 ± 5,276	5,102 ± 531	211 ± 3	–16.1835 ± 2.1303	3,761 ± 493	–29,325 ± 3,482	16,981 ± 1,183	228 ± 3
		Probability levels							
Treatment (T)		<0.001	<0.001	0.96	<0.001	<0.001	<0.001	<0.001	<0.001
Year (Y)		<0.001	<0.001	<0.001	0.68	0.32	0.04	0.048	<0.001
T × Y		0.57	0.60	0.83	0.001	0.002	<0.001	0.60	0.06

[a]Treatments differed in the amount of daily feed offered from weaning to 205 d of age: HIGH = 263 kcal ME/$(BW_{kg})^{0.75}$, MEDIUM = 238 kcal ME/$(BW_{kg})^{0.75}$, and LOW-HIGH = 157 kcal ME/$(BW_{kg})^{0.75}$ for Phase 1 and 277 kcal ME/$(BW_{kg})^{0.75}$ for Phase 2.

treatment × year interaction for weight gain ($P < 0.001$). In 1996, HIGH heifers gained 97.8 ± 2.0 kg, MEDIUM heifers gained 83.1 ± 2.5 kg, and LOW-HIGH heifers gained 113.0 ± 2.5 kg. In 1997, HIGH heifers gained 72.6 ± 2.0 kg, MEDIUM heifers gained 73.2 ± 1.7 kg, and LOW-HIGH heifers gained 96.2 ± 2.2 kg. There was a treatment × year interaction for weight gain over the entire developmental period (Phase 1 + Phase 2; $P = 0.003$). In 1996, HIGH heifers gained 149.8 ± 3.2 kg, MEDIUM heifers gained 121.2 ± 3.6 kg, and LOW-HIGH heifers gained 130.8 ± 3.1 kg, whereas in 1997 HIGH heifers gained 136.6 ± 2.8 kg, MEDIUM heifers gained 123.5 ± 2.5 kg, and LOW-HIGH heifers gained 112.8 ± 3.1 kg.

As designed, ME intake during Phase 1 differed between treatments ($P = 0.001$). Heifers on the HIGH treatment consumed 1,229 ± 7 Mcal/heifer, those on the MEDIUM treatment consumed 1,096 ± 6 Mcal/heifer, and those on the LOW-HIGH treatment consumed 819 ± 6 Mcal/heifer. During Phase 2 ME intake did not differ among treatments ($P = 0.16$). Heifers on the HIGH treatment consumed 1,843 ± 53 Mcal/heifer, those on the MEDIUM treatment consumed 1,758 ± 16 Mcal/heifer, and those on the LOW-HIGH treatment consumed 1,834 ± 24 Mcal/heifer. Treatments differed in total ME intake ($P < 0.001$) for the development period; heifers on the HIGH treatment consumed 3,072 ± 59 Mcal/heifer, those on the MEDIUM treatment consumed 2,854 ± 21 Mcal/heifer, and those on the LOW-HIGH treatment consumed 2,652 ± 19 Mcal/heifer.

The ratio of weight gain to ME intake was lower ($P \leq 0.01$; Table 3) for heifers on the LOW-HIGH treatment than for those on the other treatments during Periods 1 and 2. However, after increasing the feed offered, heifers on the LOW-HIGH treatment had a higher ($P \leq 0.03$) weight gain:ME intake ratio than those on the other treatments during Periods 3 and 4. During Period 5, the weight gain:ME intake ratio was lower for heifers on the HIGH treatment ($P \leq 0.002$) than for those on the other treatments. Treatments did not differ in the weight gain:ME intake ratio during Period 6 ($P = 0.17$). The weight gain:ME intake ratio for the entire developmental period (Phase 1 + Phase 2) did not differ between the HIGH (0.047 ± 0.001 kg/Mcal) and LOW-HIGH (0.046 ± 0.0002 kg/Mcal; $P = 0.60$) heifers, but both the HIGH ($P = 0.01$) and LOW-HIGH ($P = 0.03$) heifers had higher ratios than the MEDIUM (0.043 ± 0.0002 kg/Mcal) heifers.

Breeding

At the beginning of breeding, heifers on the HIGH treatment were taller at the hips and weighed more than heifers in the other two treatments (Table 4). There was a treatment × year interaction ($P = 0.046$) for ADG during breeding. In 1996 hifers on the HIGH (0.72 ± 0.02 kg/d), MEDIUM (0.80 ± 0.03 kg/d), and LOW-HIGH (0.76 ± 0.02 kg/d) treatments did not differ in ADG ($P > 0.05$). However, in 1997 heifers on the LOW-HIGH treatment (0.59 ± 0.03 kg/d) had a higher ADG than those on the HIGH (0.46 ± 0.03 kg/d) and the MEDIUM treatments (0.48 ± 0.04 kg/d; $P < 0.05$). Differences in ADG were not sufficient to change the ranking of BW at the end of breeding (Table 4). At palpation, heifers in the HIGH treatment were still heavier ($P = 0.02$), but hip height was not different among the treatments. The proportion of heifers that were diagnosed pregnant did not differ among treatments (Table 4).

Parturition and Postparturition

The percentage of cows that calved, expressed as a percentage of the cows exposed, did not differ with treatment ($P = 0.83$) or year (89.7%; $P = 0.29$). Age of cows at parturition (709 ± 2 d; $P = 0.83$) and time from first bull exposure to calving (297 ± 1 d; $P = 0.38$) did not differ across treatments. Cows from the HIGH treatment (409 ± 4 kg) were heavier at parturition than cows from the MEDIUM (395 ± 4 kg; $P = 0.006$) or LOW-

Table 3. Weight gain:ME intake ratio (kg/Mcal) during heifer development between weaning and breeding, mean ± SE

		Period[b]					
Treatment[a]	n	1	2	3	4	5	6
HIGH	4	0.048 ± 0.004[c]	0.045 ± 0.003[c]	0.047 ± 0.002[c]	0.050 ± 0.005[c]	0.050 ± 0.004[c]	0.039 ± 0.002[c]
MEDIUM	4	0.043 ± 0.005[c]	0.037 ± 0.002[c]	0.041 ± 0.003[c]	0.048 ± 0.002[c]	0.059 ± 0.006[d]	0.032 ± 0.003[c]
LOW-HIGH	4	0.027 ± 0.005[d]	0.011 ± 0.005[d]	0.081 ± 0.001[d]	0.056 ± 0.003[d]	0.062 ± 0.004[d]	0.037 ± 0.003[c]
		Probability levels					
Treatment (T)		0.01	0.001	<0.001	0.03	0.001	0.17
Year (Y)		0.02	0.63	0.60	0.001	<0.001	0.07
T × Y		0.60	0.10	0.13	0.28	0.19	0.88

[a]Treatments differed in the amount of daily feed offered from weaning to 205 d of age: HIGH = 263 kcal ME/(BW_{kg})$^{0.75}$, MEDIUM = 238 kcal ME/(BW_{kg})$^{0.75}$, and LOW-HIGH = 157 kcal ME/(BW_{kg})$^{0.75}$ for the first 83 d (Periods 1 and 2) and 277 kcal ME/(BW_{kg})$^{0.75}$ for the rest of the 205 d (Periods 3 through 6).

[b]Period 1 (0 to 42 d), Period 2 (43 to 84 d), Period 3 (85 to 112 d), Period 4 (113 to 140 d), Period 5 (141 to 168 d), and Period 6 (169 to 205 d) represent feeding periods after weaning.

[c,d]Within a column, treatment means without a common superscript letter differ ($P < 0.05$).

Table 4. Weights and heights of heifers at breeding and palpation and pregnancy rates of yearling heifers

	Breeding[b]					Palpation[c]			
Treatment[a]	n	Hip height, cm	Initial BW, kg	n	Final BW, kg	n	BW, kg	Hip height, cm	Pregnant, %
HIGH	94	121 ± 0.3^{d}	337 ± 3^{d}	94	373 ± 3^{d}	94	393 ± 3^{d}	125 ± 0.4	90.4
MEDIUM	94	120 ± 0.3^{e}	324 ± 3^{e}	94	362 ± 3^{e}	94	384 ± 3^{e}	124 ± 0.3	92.6
LOW-HIGH	94	120 ± 0.3^{e}	319 ± 2^{e}	93	361 ± 3^{e}	93	383 ± 3^{e}	124 ± 0.4	91.4
1996	120	120 ± 0.3^{f}	328 ± 2	120	378 ± 2^{f}	120	401 ± 3^{f}	127 ± 0.3^{f}	91.7
1997	162	121 ± 0.3^{g}	326 ± 3	161	356 ± 2^{g}	161	376 ± 2^{g}	123 ± 0.2^{g}	91.3
		Probability levels							
Treatment (T)		0.01	<0.001		0.03		0.02	0.14	0.85
Year (Y)		0.02	0.45		<0.001		<0.001	<0.001	0.87
T × Y		0.25	0.08		0.40		0.35	0.12	0.31

[a]Treatments differed in the amount of daily feed offered from weaning to 205 d of age: HIGH = 263 kcal ME/$(BW_{kg})^{0.75}$, MEDIUM = 238 kcal ME/$(BW_{kg})^{0.75}$, and LOW-HIGH = 157 kcal ME/$(BW_{kg})^{0.75}$ for the first 83 d and 277 kcal ME/$(BW_{kg})^{0.75}$ for the rest of the 205 d.
[b]Heifers were 412 ± 1 d of age at the start of breeding and breeding lasted 63 d.
[c]Palpation occurred 72 d after the end of breeding.
[d,e,f,g]Within a column and main treatment comparison, means without a common superscript letter differ ($P < 0.05$).

HIGH (396 ± 4 kg; $P = 0.02$) treatments. Cows born in 1996 calved at heavier BW (418 ± 3 kg) than cows born in 1997 (386 ± 3 kg; $P < 0.001$).

Calf birth weights did not differ with treatment (33.7 ± 0.3 kg; $P = 0.80$). Bull calves (34.9 ± 0.5 kg) weighed more than heifer calves (32.5 ± 0.4 kg; $P < 0.001$), and calves of cows born in 1996 (37.0 ± 0.4 kg) weighed more than calves of cows born in 1997 (31.1 ± 0.4 kg; $P < 0.001$). Heifers raised on the HIGH (19%), MEDIUM (21%), and LOW-HIGH (25%) treatments did not differ in the percentage of heifers requiring assistance at parturition ($P = 0.31$). Heifers giving birth to bull calves tended ($P = 0.07$; 27%) to require more assistance than heifers giving birth to heifer calves (18%).

The second-calf pregnancy rate (92.8%) for cows with a nursing calf at the start of breeding (n = 208) did not differ among treatments ($P = 0.83$) or across years ($P = 0.56$). Likewise, the second-calf pregnancy rate (92.2%) for cows that parturated but did not have a calf at side at the start of breeding (n = 51) did not differ among treatments ($P = 0.19$) or across years ($P = 0.10$).

Preweaning BW of calves did not differ across treatments ($P > 0.27$). Calves weighed 51 ± 1 kg at 30 d of age, 77 ± 1 kg at 60 d of age, 106 ± 1 kg at 90 d of age, 132 ± 1 kg at 120 d of age, 154 ± 2 kg at 150 d of age, and 175 ± 2 kg at 180 d of age. Weaning BW of calves did not differ across treatments (191 ± 2 kg; $P = 0.60$). Male calves (53 ± 1 kg) were heavier than female calves (49 ± 1 kg) at 30 d and at weaning (185 ± 2 kg vs 198 ± 3 kg; $P > 0.03$). Calves that were born later in the calving season were heavier at 30 d and 60 d, but they had lower BW at 90 d, 120 d, 150 d, 180 d, and weaning.

Body weight of lactating cows did not differ across treatments ($P > 0.19$). Cows weighed 374 ± 4 kg at 30 d of lactation, 418 ± 3 kg at 60 d of lactation, and 441 ± 4 kg at 90 d of lactation. Cow BW did not differ with the sex of the nursing calf ($P > 0.51$). Weight of cows at weaning did not differ with treatment (425 ± 3 kg; $P = 0.13$). Cows with later parturition dates were heavier at 30, 60, and 90 d of lactation.

After adjusting for breeding injuries, twins, and calves that escaped from their pen, there was a treatment × year interaction ($P = 0.02$) for weaning percentage. Heifers born in 1996 and reared on the LOW-HIGH treatment weaned fewer calves (50%) per cow exposed than those on the MEDIUM (87%; $P < 0.001$) treatment and tended to wean fewer calves than those on the HIGH treatment (68%; $P = 0.097$). Weaning rates of heifers born in 1997 did not differ among the LOW-HIGH (76%), MEDIUM (76%) and HIGH (74%) treatments. The differences in weaning rates were partially due to treatment differences in calf survival rates ($P = 0.02$). Calf survival rate on the LOW-HIGH treatment (73%) was lower than that on the MEDIUM treatment (89%; $P = 0.007$) but did not differ from that on the HIGH treatment (81%; $P = 0.26$).

Discussion

Like the studies of Clanton et al. (1983) and Lynch et al. (1997), less feed was used to develop heifers that were fed for compensatory gain than was used by heifers that had a steady rate of growth. Although less feed was used to develop LOW-HIGH heifers, they also had a lighter BW at breeding than the HIGH heifers. If we assume that the LOW-HIGH heifers would gain the weight difference at the same efficiency as in Period 6, then we would estimate that a similar amount of feed would be required to reach a common BW in the HIGH and LOW-HIGH treatments. Like this study, other studies have reported that a similar amount of feed is required to raise heifers to a common BW when they are either grown rapidly or grown using compensatory gain (Yanbayamba and Price, 1991; Carstens et al., 1997). In the study of Clanton et al. (1983) less feed was required to reach a common BW by the heifers that had been raised using compensatory gain than by heifers that grew at a constant rate. These findings suggest that the efficiency of gain of heifers undergoing compensatory gain can vary.

In the current study, the efficiency of gain over the entire developmental period did not differ between the HIGH and LOW-HIGH heifers, but both were higher than the MEDIUM heifers. The higher efficiency in the HIGH heifers compared with the MEDIUM heifers may be due to dilution of the maintenance requirement. Heifers that undergo compensatory gain typically have greater efficiencies of gain in the refeeding period (Park et al., 1987; Yanbayamba and Price, 1991). The greater efficiency of gain for the LOW-HIGH heifers in Phase 2 offset the lower efficiency of gain in Phase 1 in our study. A number of factors may influence the overall efficiency of the development program for heifers undergoing compensatory gain. Those factors include the length and severity of feed restriction and the length and feed level of the refeeding phase. The current study demonstrates that the increase in efficiency during the refeeding phase is not constant. Rather, the efficiency of gain is higher during the early periods of the refeeding phase and decreases over time. These findings would suggest that estimation of the overall efficiency of weight gain for heifer development would partially be influenced by the length of the refeeding period. Collectively these studies suggest that using compensatory gain in heifer development programs may provide alternatives in timing the use of feed resources and that the quantity of feed required to raise heifers depends on the magnitude and length of feed restriction and refeeding.

The BW advantage of the HIGH treatment at breeding was maintained through parturition. The greater BW was not associated with an increase in the percentage of heifers diagnosed pregnant or with an increase in the calving percentage. A number of studies have demonstrated that lightweight heifers have a reduced pregnancy rate (Wiltbank et al., 1969; Short and Bellows, 1971; Ferrell, 1982). However, it is generally acknowledged that as long as a minimum proportion of mature BW (55 to 65%; NRC, 1996) is met, calving percentage is not impaired. In the current study, heifers on the LOW-HIGH treatment had reached 57% of their mature weight by the beginning of breeding, where mature weight was considered to be the weight of mature cows of the same genetic type at a body condition score of 5.5 (Freetly et al., 2000). Because treatments did not differ in days from first bull exposure to parturition and age at parturition, we conclude that all treatments met the required proportion of mature weight before the beginning of breeding.

Previous studies have reported that heifers that grow slowly between 3 to 9 mo of age have an increased milk yield. Many of these studies have been conducted in dairy heifers that are removed from the cow at an early age, which allows nutrient intake to be closely controlled (Swanson, 1960; Gardner et al., 1977; Little and Kay, 1979). Johnsson and Obst (1984) demonstrated similar findings in beef heifers removed from the cow at an early age. Heifers that have access to supplemental feed before weaning also have decreased milk yield as cows compared with calves that are not creep-fed (Hixon et al., 1982). Production practices commonly do not afford the opportunity to nutritionally manage the beef heifer until weaning, which often occurs around 5 to 7 mo of age. Because of the necessity to reach a minimum BW before breeding, the only viable option to nutritionally manipulating mammary gland development in weaned heifers is through feed restriction followed by periods of plentiful feed and rapid weight gain. A number of studies in Holstein heifers suggest that compensatory gain can be used to increase milk production (Park et al., 1987, Peri et al., 1993; Carstens et al., 1997). Peri et al. (1993) found that 175-d-old Holstein heifers that were feed-restricted to gain 0.62 kg/d for 119 d and were realimented to gain 1.16 kg/d had a higher milk yield than heifers that gained 0.77 kg/d in the first 119 d and 0.71 kg/d during the next 63 d. Similarly, Park et al. (1987) found that milk yield was increased in Holstein heifers (7.6 mo) that were raised on a stair-stepped growth pattern in which growth was twice restricted, followed by rapid growth. Carstens et al. (1997) reported that heifers with interrupted growth patterns had smaller mammary glands that tended to have a larger proportion of parenchymal tissue.

It has been demonstrated that the isometric period of mammary growth starts around 2 to 3 mo of age and continues until the heifer is near puberty (Sinha and Tucker, 1969). It is during this period that nutritional influences on milk production occur (Sejrsen et al., 1982). Presumably, increased milk yield would result in differences in calf weight gain. In the current study, no differences were observed in calf BW among the treatments across calf ages. The absence of a difference suggests that milk production was not affected by prebreeding treatments. In the current study, heifers were weaned at 203 d of age, and their preweaning ADG was 837 g/d. The high preweaning ADG may have affected mammary development before the postweaning treatments were imposed, resulting in a lack of difference in calf BW. Johnsson and Obst (1984) reported that heifers gaining 0.55 kg/d from 2 to 8 mo of age had higher milk yields than heifers that gained 0.67 kg/d, or more, over the same period, regardless of their ADG after 8 mo of age.

Calf BW at a given age was influenced by the date the calf was born. Calves with later birth dates had heavier BW at 30 and 60 d of age. These heavier weights are probably the result of greater nutrient availability for the cows compared with cows that calved early. The average date of birth was March 5, and calving ranged from February 9 through April 17. High-quality forage is usually available in the first part of May at the U.S. Meat Animal Research Center (Waller and Moser, 1986). Calves born later in the calving season were lighter at 90, 120, 150, and 180 d of age. This may be the result of several factors. One factor is that as forage quality begins to decrease in late summer, milk production may have been depressed more in cows that were in middle lactation than in cows in late lactation. The second factor may have been that younger calves are not as adept at foraging as their older counterparts when forage quality decreases.

Based on the results of this study we conclude that altering postweaning growth patterns through feed availability did not affect the proportion of heifers that bred as yearlings or as 2-yr-olds and that pattern of growth during heifer development did not affect the growth of heifers' calves. In 1 yr calf survival was lower in LOW-HIGH heifers, suggesting a potential negative impact on the production system when compensatory gain is used to raise replacement heifers; however, compensatory gain offers a potential option in management of feed resources.

Implication

As long as replacement heifers grow to meet a minimal body weight before mating, patterns of growth may be altered in the postweaning period without a decrease in the ability of the heifer to conceive or a decrease in her calf's growth potential. However, limit-feeding heifers may reduce first-calf survival. Altering postweaning gain by modifying the quantity of feed offered can be used to optimize feed resources in replacement heifer production.

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